

Feasibility Study Preliminary Documented Safety Analysis for In Situ Vitrification at the Radioactive Waste Management Complex Subsurface Disposal Area

George E. Santee Jr. Science Applications International Corporation June 2003

Idaho National Engineering and Environmental Laboratory Bechtel BWXT Idaho, LLC

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Idaho National Engineering and Environmental Laboratory
Environmental Restoration Program
Idaho Falls, Idaho 83415

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ACRONYMS

ABRA ancillary basis for risk analysis

ACGIH American Conference of Government Industrial Hygienists

AE architectural engineering

ALARA as low as reasonably achievable

AMWTP Advanced Mixed Waste Treatment Project

ANL-W Argonne National Laboratory-West

ANSI American National Standards Institute

ARAR applicable or relevant and appropriate requirement

ARF airborne release fraction

ASME American Society of Mechanical Engineers

BBWI Bechtel BWXT Idaho, LLC

BLEVE boiling liquid-expanding vapor explosion

CERCLA Comprehensive Environmental Response, Compensation and Liability Act

CF conversion factor

CFA Central Facilities Area

CFR Code of Federal Regulations

CGA Compressed Gas Association

CH contact handled

COCA Consent Order and Compliance Agreement

DBA design basis accident

DBE design basis earthquake

D&D decontamination and decommissioning

DOE Department of Energy

DOE-ID Department of Energy Idaho Operations Office

DR damage ratio

DSA documented safety analysis

EBR-I Experimental Breeder Reactor-I

EDF Engineering Design File

EPA Environmental Protection Agency

ERPG Emergency Response Planning Guide

FFA/CO Federal Facility Agreement and Consent Order

FHA fire hazard analysis

FR Federal Register

FS feasibility study

HDT historical data task

HEPA high-efficiency particulate air

HWD hazardous waste determination

HVAC heating, ventilating, and air conditioning

ICDF INEEL CERCLA Disposal Facility

ICP Idaho Completion Project

INEEL Idaho National Engineering and Environmental Laboratory

INTEC Idaho Nuclear Technology and Engineering Center

ISV in situ vitrification

LANL Los Alamos National Laboratory

LCO limiting condition for operations

LEL lower explosive limit

LFL lower flammability limit

LLW low-level waste

LPF leak path factor

MAR material at risk

NEC National Electrical Code

NFPA National Fire Protection Association

NPL National Priorities List

NRC Nuclear Regulatory Commission

NSB nearest site boundary

ORNL Oak Ridge National Laboratory

ORPS Occurrence Reporting Processing System

OSH occupational safety and health

OSHA Occupational Safety and Health Administration

OU operable unit

PC performance category

PCB polychlorinated biphenyl

PCU process control unit

PDSA preliminary documented safety analysis

PERA preliminary evaluation of remedial alternatives

PPE personal protective equipment

QA quality assurance

RCRA Resource Conservation and Recovery Act

RCT radiological control technician

RF respirable fraction

RFP Rocky Flats Plant

RH remote handled

ROD Record of Decision

RPDT recent and projected data task

RR release rate

RSAC Radiological Safety Analysis Computer Program

RT release time

RWMC Radioactive Waste Management Complex

SAR Safety Analysis Report

SARA Superfund Amendments and Reauthorization Act

SDA Subsurface Disposal Area

SR surveillance requirement

SSC structure, system, and component

ST source term

TAN Test Area North

TAP Idaho Toxic Air Pollutant regulations

TEDE total effective dose equivalent

TEEL temporary emergency exposure limit

TLV threshold limit value

TRU transuranic

TSA Transuranic Storage Area

TSDF Treatment, Storage, and Disposal Facility

TSR technical safety requirement

TWA time-weighted average

VOC volatile organic compound

WAC Waste Acceptance Criteria

WAG waste area group

WGS Waste Generator Services

WIPP Waste Isolation Pilot Plant

WMP waste management plan

E. EXECUTIVE SUMMARY

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E. EXECUTIVE SUMMARY

This executive summary provides an overview of the safety basis for in situ vitrification (ISV) at the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) within the boundaries of the Idaho National Engineering and Environmental Laboratory (INEEL). Sufficient information is presented to establish a top-level understanding of ISV at the SDA and the results of the feasibility study (FS) preliminary documented safety analysis (PDSA).

The purpose of this FS PDSA is to support remedial decisions for Operable Unit (OU) 7-13/14. OU 7-13/14 comprises the comprehensive remedial investigation and feasibility study for Waste Area Group (WAG) 7 at the INEEL. WAG 7 is the RWMC, which includes the SDA, a storage area for transuranic (TRU) waste, and miscellaneous support operations.

Information developed throughout the remedial investigation/feasibility study process is cumulatively evaluated to assess data collection activities, assumptions, and the overall strategy for completing the remediation of WAG 7. Administrative implementability is an uncertainty associated with candidate technologies for remediating the SDA. This FS PDSA provides the basis for evaluating the safety issues and concerns associated with the technology and its implementation in the SDA. This FS PDSA is not approved for construction per the requirements of Title 10 Code of Federal Regulations (CFR) Part 830 Subpart B.

E.1 Facility Background and Mission

The RWMC was established in the early 1950s as a disposal site for solid low-level waste generated by operations at the INEEL and other U.S. Department of Energy (DOE) laboratories. Radioactive waste materials were buried in underground pits, trenches, soil vault rows, and one aboveground pad (Pad A) at the SDA. Radioactive waste from the INEEL was disposed of in the SDA starting in 1952. Rocky Flats Plant (RFP)^a TRU waste was disposed of in the SDA from 1954 to 1970. Post-1970 TRU waste is kept in interim storage in containers on asphalt pads at the Transuranic Storage Area (TSA).

In August 1987, in accordance with the Resource Conservation and Recovery Act (RCRA)¹ Section 3008(h), DOE and the U.S. Environmental Protection Agency (EPA) entered into a Consent Order and Compliance Agreement.² The Consent Order and Compliance Agreement required DOE to conduct an initial assessment and screening of all solid and hazardous waste disposal units at the INEEL and set up a process for conducting any necessary corrective actions. On July 14, 1989, the EPA (under the authority granted to them by the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] of 1980,³ as amended by the Superfund Amendments and Reauthorization Act [SARA] of 1986)⁴ proposed that the INEEL be listed on the 1989 National Priorities List.⁵ The final rule that listed the INEEL on the National Priorities List was published on November 21, 1989, in Title 54 of the Federal Register (FR) 48184, "National Priorities List of Uncontrolled Hazardous Waste Sites; Final Rule." On December 4, 1991, because of the INEEL's listing on the National Priorities List, DOE, EPA, and the Idaho Department of Health and Welfare entered into the Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory.

The strategy for assessing buried waste at the INEEL under the CERCLA (42 USC § 9601 et seq.) includes the analyses of waste treatment technology options for the remediation of the RWMC. The waste

E-2

a. The Rocky Flats Plant, located 26 km (16 mi) northwest of Denver, Colorado, was renamed the Rocky Flats Environmental Technology Site in the mid-1990s. In the late 1990s, it was again renamed to its present name, the Rocky Flats Plant Closure Project.

under investigation is buried in the SDA within the RWMC. The types of remedial alternatives being evaluated for the buried waste include containment, in situ treatment, retrieval and ex situ treatment, and combinations of technologies. Seven preliminary remedial action alternatives for remediation of the SDA have been identified in the "Preliminary Evaluation of Remedial Alternatives for the SDA" (PERA) report.⁸ The ISV technology is one of the alternatives among the situ technologies under evaluation.

E.2 Facility Overview

The ISV system will be designed and constructed to meet SDA remediation requirements. The system description presented in this summary is based on the current design of the GeoMelt technology licensed by AMEC Earth & Environmental, Inc. The ISV process is a technology for treating soils and waste materials containing hazardous, radioactive, and mixed contaminants. The process involves electrically melting soil and buried waste materials using electrodes placed in the waste seam. The molten soil and waste are allowed to cool and solidify into a highly leach-resistant monolith with properties similar to volcanic rock. To initiate the ISV process, electrodes are inserted into clean overburden soil above the waste seam. Trenches are excavated in the clean overburden and a mixture of graphite and glass frit is placed between the electrodes to form a conductive starter path. Additional overburden may be placed to ensure that waste is not disturbed when placing the starter path and electrodes. An electrical current passed between the electrodes generates temperatures that melt the soil. The graphite is consumed by oxidation as the molten zone grows and incorporates the soil contaminants and produces a vitreous mass. Convection currents within the melt mix the refractory waste constituents (such as nonvolatile metals and radionuclides) to homogeneity while the remaining constituents are pyrolyzed in the subsurface or volatilized and processed by the off-gas treatment system.

The starter path is created using a backhoe to excavate trenches that are filled with a layer of starter path material. Four steel tubes are inserted vertically, and the trenches are backfilled with the excavated soil. The tubes provide holes for guiding the electrodes to the desired starting elevation. When voltage is first applied to the electrodes in the ISV process, a flow of electrical current is established through the electrically conductive, buried starter path containing powdered graphite and glass frit. The resultant discharge of joule heat in the starter path raises starter path temperatures. As the starter path melts, soil immediately adjacent to the starter path begins to melt and mix with the molten frit. The electrodes gradually sink through the molten soil into the waste zone under their own weight, or, alternately, they can periodically be held at a selected depth using mechanical guides to help achieve greater melt widths.

Since underground items such as pipelines or power lines would be destroyed if they come into contact with the melt, any underground utilities in the vicinity of areas to be treated should be relocated to avoid damage. Additionally, any underground metal items that are in contact with the melt would pose an electrical shock hazard, until melt subsidence breaks contact between the melt and the metal item. Prior to treating an area, metal items that extend beyond the exclusion area must be identified and actions must be taken in accordance with standard industrial practices to protect personnel from the electric shock hazard. Probes in a treatment area should be disconnected before ISV processing and metal items protruding from the treatment area should not be allowed to contact the off-gas hood.

During ISV processing, off-gas from decomposition and vaporization of waste materials is collected by a hood over the melt area and routed to a treatment system where the off-gases are preheated and passed through a high-efficiency particulate air (HEPA) prefilter. Then the gases flow to the primary off-gas treatment system where they can be treated by wet processes.

In the wet process, the gases are cooled and scrubbed by a quencher and tandem nozzle scrubber. A vane separator followed by a condenser and a second vane separator removes water aerosols in the saturated gas stream. The gases are then reheated to ensure a temperature well above the dew point to

prevent condensed water impingement on the downstream HEPA filters. In the final stage, the off-gas is passed through two stages of HEPA filters and a thermal oxidizer.

Most of the primary system components are contained in three transportable trailers. These trailers include an off-gas treatment trailer, a process control trailer, and a support trailer. All three trailers are mounted on wheels to accommodate movement over a compacted ground surface. The entire process is monitored and controlled from the process control station. In addition, a backup power supply is used to provide auxiliary power to critical off-gas treatment and process control components in case of line power loss.

The RWMC facilities located nearest to the project facilities are as follows:

- An OU 7-10 retrieval structure and rails, a process building, a chemical warehouse, and support facilities that were constructed during an OU 7-10 project by a previous contractor, then abandoned before use
- Activities being conducted at the SDA for removal of organic contamination in the vadose zone
- Active low-level waste pit at the SDA
- Heavy equipment storage shed (WMF-609)
- Construction and field support trailers (WMF-645, WMF-646, and WMF-657)
- Radiological Control Field Office (WMF-601)
- RWMC Highbay (WMF-602)
- Advanced Mixed Waste Treatment Project (AMWTP) facility.

Significant physical interfaces with RWMC systems include connection to the RWMC electrical power systems.

E.3 Facility Hazard Categorization

10 CFR 830 Subpart B requires the categorization of DOE facilities based on the level of potential hazard the facility poses to the on-Site workers and off-Site public. The RWMC SDA is classified as a Hazard Category 2 facility in accordance with the guidelines in DOE Order 5480.23, "Nuclear Safety Analysis Report," DOE Standard DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports," and DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis." The ISV operations at the RWMC SDA are categorized as Category 2, based on the RWMC SDA categorization and confirmed by the hazard and accident analysis in Chapter 3 of this document.

E.4 Safety Analysis Overview

This FS PDSA is prepared to ensure that the necessary design features are identified and categorized as safety-class or safety-significant during design. The results of the FS PDSA provide the foundation for the final documented safety analysis (DSA). Potential hazards associated with the project are identified through review of existing safety documentation and analyses, shipping records, DOE operating history, designs, and process descriptions. The ISV technology is being considered for remediation of the RFP TRU waste in the pits (1-6, 9-12) and trenches (1-15) and on Pad A. The waste on Pad A will not be treated there, but may be transferred to a pit for disposal and treatment.

The significant hazards (those which could initiate a release) associated with the project facility are listed below:

- Operational: high and low voltages, high-temperature systems, high pressures, overpressurized containers, mechanical and moving equipment, combustible materials, compressed gases, flammable gases, flammable liquids, pyrophoric metals, explosive materials, nonradioactive hazardous materials, ionizing radiation, radioactive materials, fissile materials, and pit subsidence
- External: aircraft impact, vehicle impact, range fires, boiling liquid-expanding vapor explosion, fuel air explosion, loss of electrical power, and pit subsidence
- **Natural events:** earthquake, flooding, high winds, lightning, temperature extremes, and volcanic eruption.

The applicable hazards are qualitatively evaluated to identify potential unmitigated release or exposure scenarios. For each scenario, preventive and mitigative features are listed and consequence and frequency levels are qualitatively assigned assuming unmitigated conditions. The consequences and frequencies of accidents are combined in applicable risk matrices to determine if safety-class or safety-significant structures, systems, and components (SSCs) are required, and if technical safety requirements (TSRs) or other safety requirements are needed. A bounding and representative set of accidents is selected from the list of accidents identified in this hazard evaluation. These scenarios are a direct radiation exposure, a container deflagration, an underground fire, a melt expulsion, and a loss of confinement.

In accordance with direction in DOE-STD-3009-94, ¹² consequences to the facility workers are qualitatively assessed and equipment that is safety significant is identified in the hazard evaluation of Chapter 3. This qualitative evaluation is based on the nature of the materials involved and the assumptions that releases in the immediate area are unmitigated and unconfined and that the worker is directly exposed. For comparison with accident evaluation guidelines, the radioactive and nonradioactive consequences of accidents are calculated at receptor locations where the on-Site co-located worker (100 m directly downwind from the point of release) and off-Site individuals (nearest INEEL Site boundary [NSB] at 6 km from the RWMC) are located.

The likelihoods for accident scenarios are based on the initiator likelihood and the likelihood for the assumed material at risk (MAR). Three different MAR likelihoods are evaluated. These likelihoods are anticipated for average inventories, unlikely for limiting inventories, and extremely unlikely for bounding inventories. The results from the quantitative analysis of exposures to radioactive and nonradioactive hazardous materials and a comparison of these results to evaluation guidelines established by the U.S. Department of Energy Idaho Operations Office (DOE-ID)¹¹ are summarized in Table E-1 for radioactive materials and in Table E-2 for nonradioactive hazardous materials. Consequences that exceed the corresponding evaluation guideline are shown in *bold italics*. Concentrations for the co-located worker and the public are presented in Table E-2 for the ten nonradioactive materials with the largest ratio of 6 km concentration to 6 km evaluation guideline. The radiation evaluation guidelines for the off-site public are not exceeded in any of the scenarios. The evaluation guidelines for nonradioactive hazardous material exposures to the off-Site public are challenged or exceeded for the melt expulsion and the loss of confinement scenarios.

Table E-1. Postulated accident scenarios and results from analysis of radioactive material releases.

Accident Scenario	Frequency Category	Co-located Worker Total Effective Dose Equivalent (rem)	Co-Located Worker Evaluation Guidelines for Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)	
Direct radiation exposure	Unlikely	0.89	25	0.00025	5
Container deflagration					
Limiting Source Term	Extremely Unlikely	33	100	0.046	25
Average Source Term	Unlikely	0.24	25	0.00033	5
Underground fire					
Average Source Term	Extremely Unlikely	0.77	100	0.0063	25
Melt expulsion					
Bounding Source Term	Extremely Unlikely	490	100	0.68	25
Limiting Source Term	Unlikely	170	25	0.23	5
Average Source Term	Unlikely	160	25	0.22	5
Loss of Confinement					
Bounding Source Term	Extremely Unlikely	38	100	0.052	25
Limiting Source Term	Unlikely	13	25	0.018	5
Average Source Term	Unlikely	13	25	0.017	5
NOTE: Bold italics denotes ev	aluation guideline excee	eded.			

Table E-2. Postulated accident scenarios and results from analysis of nonradioactive material releases.

Table E-2. Postulated	accident scenarios a	nd results from anal	*	ioactive material	releases.
			Co-Located		
		Co-located Worker	Worker	Public (6 km)	Public
		Exposure	Evaluation	Exposure	Evaluation
Accident		Concentration	Guidelines	Concentration	Guidelines
Scenario	Substance	(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)
Direct radiation exposur	re				
•	-	-	-	-	-
Container deflagration					
Limiting Source Term	Phosgene	35	4	0.048	0.8
C	Hydrochloric Acid	140	224	0.19	30
	Carbon tetrachloride	1,500	4,790	2.1	639
	Hydrofluoric acid	36	41	0.049	16.4
	Sodium nitrate	8.9	100	0.012	7.5
	Uranium	0.87	10	0.0012	1
	Tributyl phosphate	5.0	300	0.0069	10
	Tetrachloroethylene	370	6,890	0.51	1,378
	Potassium nitrate	4.6	500	0.0063	20
	Trichloroethylene	460	26,900	0.63	2,690
Average Source Term		0.45	4	0.00061	0.4
Ü	Hydrochloric Acid	1.1	224	0.0016	4.5
	Carbon tetrachloride	26	4,790	0.036	128
	Hydrofluoric acid	0.30	41	0.00041	1.5
	Sodium nitrate	0.071	100	9.8E-05	1
	Uranium	0.0072	10	9.8E-06	0.6
	Potassium nitrate	0.038	500	5.2E-05	3.5
	Trichloroethylene	3.8	26,900	0.0052	538
	Tributyl phosphate	0.041	300	5.5E-05	6
	Nitric acid	0.019	200	2.6E-05	3
Underground fire					
Average Source Term	Phosgene	0.58	4	0.0048	0.8
C	Carbon tetrachloride	34	4,790	0.28	639
	Hydrochloric Acid	1.5	224	0.012	30
	Hydrofluoric acid	0.37	41	0.0031	16.4
	Tributyl phosphate	0.051	300	0.00042	10
	Tetrachloroethylene	4.0	6,890	0.033	1,378
	Trichloroethylene	4.8	26,900	0.040	2,690
	Nitric acid	0.025	200	0.00020	15
	1,1,1-trichloroethane	4.9	19,250	0.040	3,850
	Sodium nitrate	0.0093	100	7.6E-05	7.5
Melt expulsion					
Bounding Source	Phosgene	430	4	0.58	0.8
Term	Lead	100	100	0.14	0.25
	Sodium nitrate	2,100	100	2.9	7.5
	Uranium	220	10	0.29	1
	Hydrochloric Acid	1,700	224	2.3	30
	Potassium nitrate	1,100	500	1.5	20
	Hydrofluoric acid	890	41	1.2	16.4
	Carbon tetrachloride	19,000	4,790	26	639
	Cadmium	8. 7	7.5	0.012	0.5
	Beryllium	0.34	0.1	0.00046	0.025
Limiting Source Term	Sodium nitrate	2,100	100	2.9	1
	Phosgene	420	4	0.58	0.4
	Lead	100	100	0.14	0.15
	Hydrofluoric acid	880	41	1.2	1.5
	Hydrochloric Acid	1,700	224	2.3	4.5

Table E-2. (continued).

Table L-2. (continued)		Co-located Worker	Co-Located Worker	Dublic (6 lcm)	Public
			Evaluation	Public (6 km)	Evaluation
Accident		Exposure Concentration	Guidelines	Exposure Concentration	Guidelines
Scenario	Substance	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)
	Substance Uranium	210	10	0.29	0.6
	Potassium nitrate		500	1.5	3.5
		1,100	7.5	0.012	0.03
	Cadmium	8.6 20	4.1	0.012	0.03
	Mercury Carbon tetrachloride	19,000	4,790	26	128
Average Source Term		1 9,000 26	100	0.036	128
	Phosgene	8.2	4	0.030	0.4
	Lead	1.2	100	0.0017	0.4
		10	41	0.0017	1.5
	Hydrofluoric acid	21	224	0.014	
	Hydrochloric Acid				4.5
	Uranium	2.6	10	0.0036	0.6
	Potassium nitrate	14	500	0.019	3.5
	Carbon tetrachloride	480	4,790	0.66	128
	Cadmium	0.11	7.5	0.00015	0.03
	Beryllium	0.004	0.1	5.5E-06	0.005
Loss of Confinement Bounding Source					
Term	Hydrofluoric acid	2,100	41	2.8	16.4
	Cadmium	20	7.5	0.028	0.5
	Tributyl phosphate	280	300	0.38	10
	Phosgene	20	4	0.027	0.8
	Mercury	47	4.1	0.064	2.05
	Lead	2.3	100	0.0032	0.25
	Nitric acid	130	200	0.18	15
	Sodium nitrate	49	100	0.068	7.5
	Uranium	5.0	10	0.0068	1
	Ammonia	390	525	0.54	105
Limiting Source Term		2,100	41	2.8	1.5
	Cadmium	20	7.5	0.027	0.03
	Mercury	47	4.1	0.064	0.1
	Sodium nitrate	49	100	0.068	1
	Phosgene	20	4	0.027	0.4
	Tributyl phosphate	280	300	0.38	6
	Nitric acid	130	200	0.18	3
	Formaldehyde	32	30	0.043	1.25
	Ammonia	390	525	0.54	17.5
	Hydrochloric Acid	78	224	0.11	4.5
Average Source Term		24	41	0.033	1.5
	Cadmium	0.25	7.5	0.00034	0.03
	Phosgene	0.38	4	0.00054	0.03
	Sodium nitrate	0.60	100	0.00032	1
	Tributyl phosphate	3.4	300	0.0046	6
	Nitric acid	1.6	200	0.0022	3
	Mercury	0.050	4.1	6.9E-05	0.1
	INICH HILV	0.030			
	•	0.20	20	0.00054	1 75
	Formaldehyde	0.39	30 525	0.00054	1.25
	•	0.39 4.7 0.96	30 525 224	0.00054 0.0064 0.0013	1.25 17.5 4.5

From Chapter 3 Table 3-9, twelve scenarios have risk bin numbers high enough that safety-significant SSCs or TSRs should be identified to protect the worker. Two of the scenarios relate to a melt expulsion. Seven of the scenarios relate to confinement system failures. The remaining three scenarios include direct radiation exposure, a boiling liquid-expanding vapor explosion (BLEVE) involving the off-gas treatment propane storage tank, and a fuel-air explosion involving the off-gas treatment propane storage tank. Five scenarios have risk bin numbers high enough that safety-class SSCs should be identified to protect the off-Site public. These scenarios relate to a melt expulsion and off-gas treatment system failures. However, a future off-gas analysis may show that the consequences are not great enough to warrant safety-class SSCs.

To protect the health and safety of the public, the following SSCs are identified as safety class:

- Off-gas hood
- Off-gas treatment system
- Primary and secondary off-gas ventilation systems
- Combustible gas monitors
- Backup power supply.

To protect the health and safety of the facility workers and the co-located workers, the following SSCs are identified as safety significant:

- Toxic gas monitors
- Propane system design.

As described in TSR-100,¹³ Programs required by CFRs (such as the radiation protection, industrial safety, hazardous material protection, and quality assurance [QA] programs) are not addressed as TSRs. TSR-level safety limits and the associated limiting control settings, and limiting conditions for operations may potentially be required for the following:

- Off-gas hood
- Off-gas treatment system (includes primary and secondary off-gas ventilation systems and combustible gas monitoring systems)
- Primary and secondary off-gas ventilation systems
- Backup power supply
- Combustible gas monitoring system
- Toxic gas monitoring system.

TSR-level administrative controls may potentially be required for the following:

- Emergency preparedness program
- Procedures and training
- Remote ISV operations

- Exclusion zone
- Controlled access to the off-gas hood and operating areas near the hood
- Monitoring for toxic gas around the periphery of the off-gas hood and in occupied areas
- Minimum staffing for ISV operations
- Hoisting and rigging program
- Maintenance and inspection program
- Fire protection program
- Maintenance of overburden thickness.^b

Worker safety is ensured by the safety-significant SSCs, TSRs, worker safety programs, and worker safety requirements identified by the hazard evaluation. Unique and important worker safety requirements include:

- Remote operations
- Exclusion zone
- Controlled access to the off-gas hood and areas near the off-gas hood
- Toxic gas monitoring system
- Procedures and training.

Impacts to the environment resulting from ISV operations will be minor. Over the 20-year history of ISV operations, several melt expulsions have occurred, but none resulted in significant environmental damage. The ISV off-gas treatment system ensures that off-gases from the melt are collected, filtered, and treated before release to the atmosphere.

E.5 Organizations

Bechtel BWXT Idaho, LLC (BBWI), is responsible for the environmental remediation program at the INEEL. INEEL's Idaho Completion Project (ICP) executes this responsibility. The project manager reports directly to the Clean/Close RWMC project director.

Organizations conducting work in the RWMC are directly accountable to the Clean/Close RWMC facility authority/operations manager for work planning, control, execution, safety, and compliance. The ICP functional support service requirements are presently being evaluated, and this section will be revised once those entities have been identified.

b. 10-cm overburden thickness assumed in the accident analyses of Section 3.4.

E.6 Safety Analysis Conclusions

The off-gas hood and the off-gas treatment system (includes the primary and secondary off-gas ventilation systems, the combustible gas monitoring system, and the backup power supply) are identified as safety-class SSCs that must be incorporated into the design. Toxic gas monitors and the propane system are identified as safety-significant design features. Prior to completing the final DSA for ISV operations on buried RFP TRU waste in the SDA, the following must be completed:

- An off-gas analysis is necessary to understand the type and quantity of emissions from normal and abnormal ISV processing operations. The analysis will specifically evaluate phosgene and hydrochloric acid concentrations and will bound the hazards related to an uncontrolled subsurface fire. The analysis will aid in determining risks from ISV processing.
- The capacity of the secondary blower in the off-gas ventilation system is described as one quarter
 the capacity of the primary blower. An analysis must be completed to determine if this secondary
 blower capacity provides adequate ventilation of the off-gas hood to maintain hood-gas
 concentrations below the LFL.

Measures that could be implemented to negate the need for safety-class SSCs include the following:

- A more detailed evaluation of contaminant transport during ISV processing to determine if safetyclass SSCs could be replaced by safety-significant SSCs
- A detailed evaluation of the distribution of the SDA inventory to identify areas that could be treated safely using ISV without safety-class SSCs.

If ISV is selected in the decision-making process for the SDA, cold and hot testing will be required during remedial design to address the following objectives:

- Understand performance, safety, and cost implications of ISV processing in waste zone voids and in heterogeneous debris and sludge waste characteristic of RFP disposals in the SDA
- Quantify the hazards associated with processing nonradioactive hazardous materials that may be co-located with RFP TRU waste
- Ensure that the off-gas hood and the off-gas treatment system are adequately sized to capture, contain, and treat off-gases from routine operations and from accident events.

E.7 Documented Safety Analysis Organization

Though this FS PDSA follows the format and content delineated in DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports," references are made to the main body of the RWMC SAR¹⁴ and SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," for site characteristic information and institutional program summary information required by DOE-STD-3009-94.

Metric and English units are used throughout the document where appropriate. For example, when referring to area or density, English units are used. When referring to weights of fissile materials, metric units are used. The approach taken is to apply the style most commonly used at the INEEL for the unit being discussed.

E.8 References

- 1. 42 USC 6901 et seq., "Resource Conservation and Recovery Act (Solid Waste Disposal Act)," *United States Code*, October 21, 1976.
- 2. DOE-ID, Consent Order and Compliance Agreement, U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; and the U.S. Geological Survey, July 10, 1987.
- 3. 42 USC 9601 et seq., "Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA/Superfund)," December 11, 1980.
- 4. Public Law 99-499, "Superfund Amendments and Reauthorization Act of 1986 (SARA)," 100 Statutes 1728, October 17, 1986.
- 5. 54 FR 29820, "National Priorities List for Uncontrolled Hazardous Waste Sites: Update 9, Federal Facilities Sites," *Federal Register*, U.S. Environmental Protection Agency, July 14, 1989.
- 6. 54 FR 48184, "National Priorities List of Uncontrolled Hazardous Waste Sites; Final Rule," *Federal Register*, November 21, 1989.
- 7. DOE-ID, Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory, Administrative Record No. 1088-06-29-120, U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; and the Idaho Department of Health and Welfare, December 4, 1991.
- 8. J. F. Zitnik, et al, *Preliminary Evaluation of Remedial Alternatives for the Subsurface Disposal Area*, INEEL/EXT-02-01258, Rev. 0, December 2002.
- 9. DOE Order 5480.23, "Nuclear Safety Analysis Report," U.S. Department of Energy, April 30, 1992.
- 10. DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports," U.S. Department of Energy, December 1992 (including Change 1, September 1997).
- 11. DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis," U.S. Department of Energy Idaho Operations Office, July 17, 2002.
- 12. DOE-STD-3009-94, "Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Documented Safety Analyses," U.S. Department of Energy, July 1994 (including Change 2, April 2002).
- 13. TSR-100, "INEEL Standardized Technical Safety Requirements (TSR) Document," Current revision.
- 14. INEEL, *Radioactive Waste Management Complex Safety Analysis Report*, INEEL-94/0226, Rev. 5, October 20, 2000.
- 15. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Current revision.

1. SITE CHARACTERISTICS

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1. SITE CHARACTERISTICS

1.1 Introduction

A description of the site characteristics important to understanding the safety basis of the Idaho National Engineering and Environmental Laboratory (INEEL) and Radioactive Waste Management Complex (RWMC) facilities is contained in Safety Analysis Report (SAR)-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Chapter 1, "Site Characteristics" and in Chapter 1 of the RWMC SAR.² Specific site characteristics that directly affect the design or the hazard and accident analysis for the in situ vitrification (ISV) treatment operations at the RWMC are identified in this chapter.

1.2 Requirements

The codes, standards, regulations, and U.S. Department of Energy (DOE) orders pertaining to INEEL Site characteristics are covered in Chapter 1 of SAR-100. There are no additional requirements that apply uniquely to the ISV treatment process.

1.3 Site Description

A description of the INEEL Site and the RWMC, including pertinent information on geography and demography is contained in Chapter 1 of SAR-100. For calculating the potential consequences of postulated accidents to an off-Site individual (the public), the distance from the RWMC to the nearest INEEL Site boundary (NSB) is 6,000 m to the south.

1.4 Environmental Description

Chapter 1 of SAR-100 contains descriptions of regional and local meteorology, hydrology, and geology. The SAR-100 descriptions of Site meteorology, hydrology, and geology also provide the basis for extreme weather conditions found in the natural phenomena threats design of the ISV treatment process. There are no additional environmental features or requirements that are unique to the ISV treatment process.

1.5 Natural Event Accident Initiators

Specific natural phenomena threats (hazards) that are potential accident initiators for INEEL facilities are identified in Chapter 1 of SAR-100. See Chapter 3 for details.

1.6 Manmade External Event Accident Initiators

External manmade threats, exclusive of sabotage and terrorism,^a that could be accident initiators for ISV operations are identified and evaluated in Chapter 3 of this Preliminary Documented Safety Analysis (PDSA).

a. The analysis of postulated accidents caused by sabotage and terrorism is not within the scope of the ISV PDSA. Identifying and controlling the risk of potential sabotage and terrorist threats at the RWMC are the responsibility of INEEL and RWMC security.

1.7 Nearby Facilities

Postulated events identified and evaluated in Chapter 3 involving ISV operations could negatively impact nearby RWMC and Advance Mixed Waste Treatment Project (AMWTP) facilities. A radioactive or nonradioactive hazardous material release could require the evacuation of nearby RWMC and AMWTP facilities.

Chapter 1 of SAR-100 describes hazardous operations at nearby INEEL facilities that could adversely impact RWMC facilities. INEEL facilities located within 15.3 km (9.5 mi) of the RWMC are the Central Facilities Area (CFA) and the Idaho Nuclear Technology and Engineering Center (INTEC). No accidents at these facilities have been identified that could adversely impact ISV operations beyond a possible need for evacuation of the RWMC.

The AMWTP is located within the boundary of the Transuranic Storage Area (TSA) at the RWMC. The AMWTP, which is currently under construction, is operated for DOE by another contractor. Potential accidents at the AMWTP will be evaluated for impacts on ISV operations after the AMWTP becomes operational and before commencing ISV operations. Identification of accidents that would adversely impact ISV operations beyond a possible need for evacuation of the RWMC is not anticipated.

1.8 Validity of Existing Environmental Analysis

Chapter 1 of SAR-100 addresses the validity of existing environmental analyses. The site characteristic assumptions contained in this SAR are compatible with those of existing environmental analyses and impact statements (such as the Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement).³

1.9 References

- 1. SAR-100, Chapter 1, "Site Characteristics," Current revision.
- 2. INEEL, Radioactive Waste Management Complex Safety Analysis Report, INEEL-94/0226, Rev. 5, October 20, 2000.
- 3. DOE, Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement, DOE/EIS-0203-F, U.S. Department of Energy, April 1995.

2. FACILITY DESCRIPTION

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2. FACILITY DESCRIPTION

2.1 Introduction

This chapter provides descriptions of the ISV structures, systems, and components (SSCs) and processes to support assumptions used in the hazard and accident analyses. These descriptions focus on all major facility features necessary to understand the hazard analysis and accident analysis. The descriptions provided herein are for information only.

2.2 Requirements

The requirements that apply to the facility are found in the following documents:

- Title 10 Code of Federal Regulations (CFR) 830 Subpart B, "Safety Basis Requirements"
- 10 CFR 835, "Radiation Protection"²
- DOE Order 5400.5, "Radiation Protection of the Public and the Environment"
- DOE Order 420.1A, "Facility Safety"⁴
- DOE-ID AE, "DOE-ID Architectural Engineering Standards."

2.3 Facility Overview

The RWMC was established in the early 1950s as a disposal site for solid low-level waste (LLW) generated by operations at the INEEL and other DOE laboratories. Radioactive waste materials were buried in underground pits, trenches, soil vault rows, and one aboveground pad (Pad A) at the Subsurface Disposal Area (SDA). Transuranic (TRU) waste from the Rocky Flats Plant (RFP)^a was disposed of in the SDA from 1954 to 1970. After 1970, incoming shipments of TRU waste were placed in interim storage in containers on asphalt pads at the TSA.

In August 1987, pursuant to the Resource Conservation and Recovery Act (RCRA) Section 3008(h), DOE and the Environmental Protection Agency (EPA) entered into a Consent Order and Compliance Agreement (COCA). The COCA required DOE to conduct an initial assessment and screening of all solid waste and/or hazardous waste disposal units at the INEEL and set up a process for conducting any necessary corrective actions. On July 14, 1989, the EPA (under the authority granted to them by the Comprehensive Environmental Response, Compensation and Liability Act of 1980 [CERCLA] [42 USC § 9601 et seq.], as amended by the Superfund Amendments and Reauthorization Act of 1986 [SARA]) proposed that the INEEL be listed on the National Priorities List (NPL) (54 Federal Register (FR) 29820). The final rule that listed the INEEL on the NPL was published on November 21, 1989, in 54 FR 44184. On December 9, 1991, because of the INEEL's listing on the NPL, the DOE, EPA, and the Idaho Department of Health and Welfare entered into the Federal Facility Agreement and Consent Order (FFA/CO). Under the FFA/CO, the INEEL is divided into 10 Waste Area Groups (WAGs). These WAGs are further subdivided into operable units (OUs). The RWMC has been designated as WAG 7 and is subdivided into 13 OUs.

a. The RFP, a DOE-owned facility located west of Denver, Colorado, was used primarily for the production of components for nuclear weapons.

The waste under evaluation is buried in the SDA within the RWMC. The layout of the SDA, including pits and trenches, is shown in Figure 2-1. The strategy for evaluating buried waste at the INEEL under CERCLA includes the analyses of waste treatment technology options for the remediation of the RWMC. The types of remedial alternatives being evaluated for the buried waste include containment, in situ treatment, retrieval and ex situ treatment, and combinations of technologies. Seven preliminary remedial action alternatives for remediation of the SDA have been identified in the "Preliminary Evaluation of Remedial Alternatives for the SDA" (PERA) report. The ISV technology is one of the alternative in situ technologies under evaluation and is a possible alternative for remediation of OU 13/14.

The SDA encompasses 97 acres of land on the western portion of the RWMC. The area includes Pad A, trenches, pits, and vaults that have been used for disposal. Currently, only Pits 17 through 20 and concrete-lined vaults are used to dispose of LLW. Dikes and drainage channels are appropriately located to channel water away from the SDA to prevent flooding. Remediation with ISV is being considered for the TRU pits and trenches (Pits 1–6 and Pits 9–12, Trenches 1–15) and Pad A. The waste on Pad A may be removed for stabilization and subsequent treatment within the SDA. Treating these areas in the SDA has been estimated to require 1,300 melts and 92 system years of operation.⁷

2.3.1 Pits and Trenches

There are 20 disposal pits and 58 trenches within the SDA. The pits and trenches are defined as TRU or non-TRU, depending on the contents. Waste has been disposed of in drums, cardboard boxes, wood boxes, metal boxes, and other containers. Most containers are breached. The types of waste and the radioactive and nonradioactive hazardous material source terms are described in Chapter 3.

The trenches are approximately 10 ft wide, 900 ft long, and on the average, 13 ft deep. Some trenches were excavated to the underlying basalt. In the late 1960s, the minimum trench depth increased from 3 to 5 ft, the bottoms of excavations were lined with at least 2 ft of soil under burden, waste was compacted by dropping a heavy steel plate on the waste in some trenches, and the soil cover was increased from a minimum of 2 ft to 3 ft. Adjacent trench centerlines were separated by no more than 16 ft. When the trenches were full, they were covered with a minimum of 2 to 3 ft of soil.

Pits are 100 ft wide, 13 to 32 ft deep, and vary in length from 200 to 1,200 ft. A soil under burden at least 2 ft thick was used to cover basalt before waste was emplaced, and a final layer of compacted soil at least 3 ft thick was used to cover buried waste. Current pits are excavated into rock to a depth of 30 ft, then backfilled with a least 3 ft of soil.

Trenches were used for both contact-handled and remote-handled radioactive waste. From 1952 through 1957, the waste was buried only in trenches.

Waste with high radiation levels was handled remotely using specially shielded containers and boom cranes. As waste disposal became more rigorously controlled, the trenches were used more frequently for high radiation waste until they were replaced by soil vaults. For some trenches, metal liners were placed over the trench as it was filled. The metal liners prevented the trench from sloughing off and provided shielding.

Beginning in 1957, the larger open pits were excavated for disposing large bulky items. Initially, waste was stacked horizontally in pits. From 1963 until 1969, drums from RFP were dumped into pits, rather than stacked, to reduce labor costs and personnel exposure.

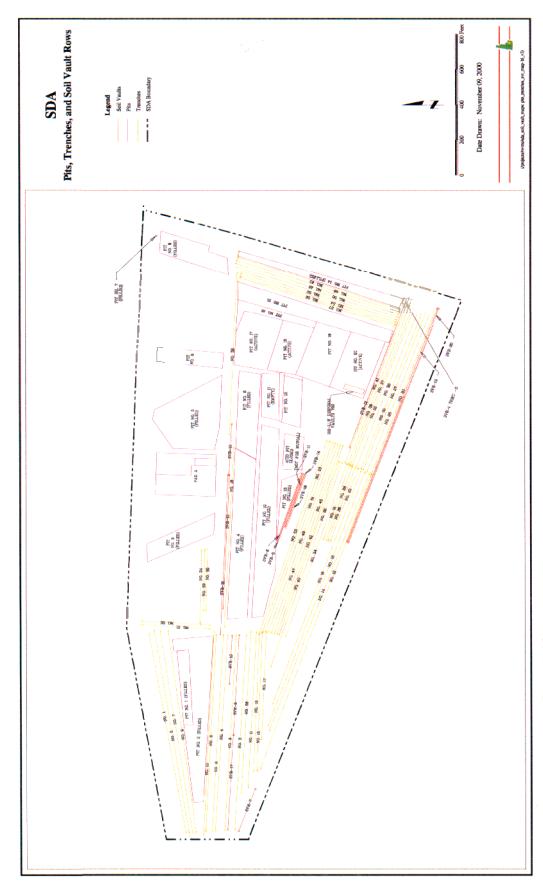


Figure 2-1. Layout of the SDA at the RWMC.

The burial of most nonradioactive hazardous material mixed wastes was terminated in 1982. Thus pits and trenches filled after that time are not expected to contain significant quantities of nonradioactive hazardous materials.

- 2.3.1.1 TRU Pits and Trenches. The TRU pits and trenches are those that operated between 1952 and 1970, when both non-TRU and TRU waste were buried at the SDA. Waste from on-Site generators was primarily non-TRU. From 1960 until 1963, non-TRU waste was also accepted from Atomic Energy Commission (AEC) licensed private entities. TRU waste was received from RFP and other generators beginning in 1954. Burial of TRU waste was discontinued in 1970. Much of this waste also contained nonradioactive hazardous material. Pits 1–6 and 9–12 and Trenches 1–10 are known to contain TRU waste. Trenches 11–15 are suspected to contain TRU waste. The remaining pits (7, 8, 13–20) and trenches (16–58) contain only non-TRU. RFP waste in drums and boxes was disposed in Pits 11 and 12 through 1972, but the drums were retrieved and the TRU drums were placed on the TSA pads. The boxes were left in Pits 11 and 12 and could contain TRU waste.
- 2.3.1.2 Non-TRU Pits and Trenches. Pits and trenches containing only non-TRU waste have been used since 1970. The same types of non-TRU waste continued to be disposed after 1970, but disposal practices improved over time. The use of trenches was terminated in 1982, and waste is currently disposed of only in pits and concrete vaults. Compaction, restrictive packaging criteria, and enlarged pit volumes were employed to improve space utilization. Close-packed array stacking was employed in the pits. Pits were expanded by using heavy equipment and explosive fracturing to remove fractured basalt from the base of the pits. An at least 2-ft-thick soil under burden was used to cover basalt before waste was emplaced, and a final layer of compacted soil at least 3 ft thick was used to cover buried waste. In 1985, a geotextile liner was incorporated into the upper portion of the pit floor soil cover to add stability to the waste stack and support mobile equipment. In recent years the waste has been carefully stacked.

2.3.2 Pad A

Pad A was constructed in 1972, as the Transuranic Disposal Area. Disposal operations were conducted on Pad A from 1972 to 1978. It is located in the north central part of the SDA that was not suited for pits or trenches because of basalt near the surface. Pad A is 243 ft wide × 328 ft long and is constructed of a 3-in.-asphalt surface over a 4-in.-gravel base. Pad A contains TRU alpha-emitting radionuclides with concentrations less than or equal to 100 nCi/g but greater than 10 nCi/g, and dose rates less than 200 mR/h at the container surface. Also, there is a small number of TRU drums on Pad A. The waste on Pad A has been completely covered with soil. For this document, it is assumed that the waste on Pad A will be removed for stabilization and subsequent treatment within the SDA.

2.3.3 ISV Process

The ISV process is a technology for the treatment of soils and waste materials containing hazardous, radioactive, and mixed contaminants. The process involves electrically melting soil and buried waste materials using electrodes placed in the waste seam. The molten soil and waste are allowed to cool and solidify into a highly leach-resistant monolith with properties similar to volcanic rock. To initiate the ISV process, electrodes are inserted into clean overburden soil above the waste seam. Trenches are excavated in the clean overburden and a mixture of graphite and glass frit is placed between the electrodes to form a conductive starter path. An electrical current passed between the electrodes generates temperatures that melt the soil. The graphite is consumed by oxidation as the molten zone grows and incorporates the soil contaminants and produces a vitreous mass. Convection currents within the melt mix the refractory waste constituents (including nonvolatile metals and radionuclides) to homogeneity, while the remaining constituents are pyrolyzed in the subsurface or volatilized and processed by the off-gas treatment system.

The starter path is created using a backhoe to excavate trenches that are filled with a layer of starter path material. Four steel tubes are inserted vertically, and the trenches are backfilled with the excavated soil. The tubes provide holes for guiding the electrodes to the desired starting elevation. When voltage is first applied to the electrodes in the ISV process, a flow of electrical current is established through the electrically conductive, buried starter path containing powdered graphite and glass frit. The resultant discharge of joule heat in the starter path raises starter-path temperatures. As the starter path melts, soil immediately adjacent to the starter path begins to melt and mix with the molten frit. The electrodes gradually sink through the molten soil into the waste zone under their own weight, or, alternately, they can periodically be held at a selected depth using mechanical guides to help achieve greater melt widths.

During ISV processing, off-gas from decomposition and vaporization of waste materials is collected by a hood over the melt area and is routed to a treatment system where the off-gases are preheated and passed through a high-efficiency particulate air (HEPA) prefilter. Then the gases flow to the primary off-gas treatment system where they can be treated by wet processes.

In the wet process, the gases are cooled and scrubbed by a quencher and tandem nozzle scrubber. A vane separator followed by a condenser and a second vane separator removes water aerosols in the saturated gas stream. The gases are then reheated to ensure a temperature well above the dew point to prevent condensed water impingement on the downstream HEPA filters. In the final stage, the off-gas is passed through two stages of HEPA filters and a thermal oxidizer.

2.4 Facility Structure

The ISV system will be designed and constructed to meet SDA remediation requirements. The system description presented in this chapter is based on the current design of the GeoMelt technology licensed by AMEC Earth & Environmental, Inc. According to a report prepared for ISV at Los Alamos National Laboratory (LANL), "the operating experience of traditional ISV is extensive, including over 300 test, demonstration and commercial melts covering a wide array of contaminants, soil types, and inclusions (debris) types. More than 80 of those melts have been performed at full field-scale." The equipment required to perform ISV functions is illustrated in Figures 2-2 and 2-3. Most of the primary system components are contained in three transportable trailers as shown in Figure 2-4. These trailers include an off-gas treatment trailer, a process control trailer, and a support trailer. All three trailers are mounted on wheels to accommodate movement over a compacted ground surface. The entire process is monitored and controlled from the process control station. In addition, a backup power supply provides auxiliary power to critical off-gas treatment and process control components in case of line power loss.

2.5 Process Description

This section describes ISV operations and associated process SSCs. The descriptions provided in this section are utilized in the hazard and accident analysis to evaluate system designs and identify systems or structures that are important to safety.

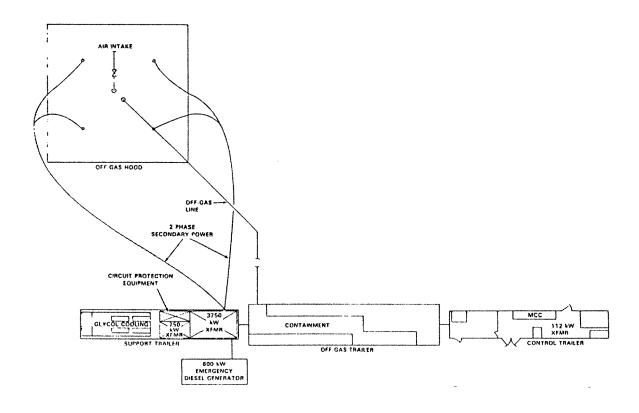


Figure 2-2. Layout of the ISV process equipment.

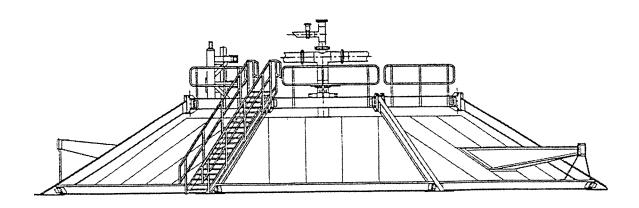


Figure 2-3. Off-gas hood for the ISV unit.

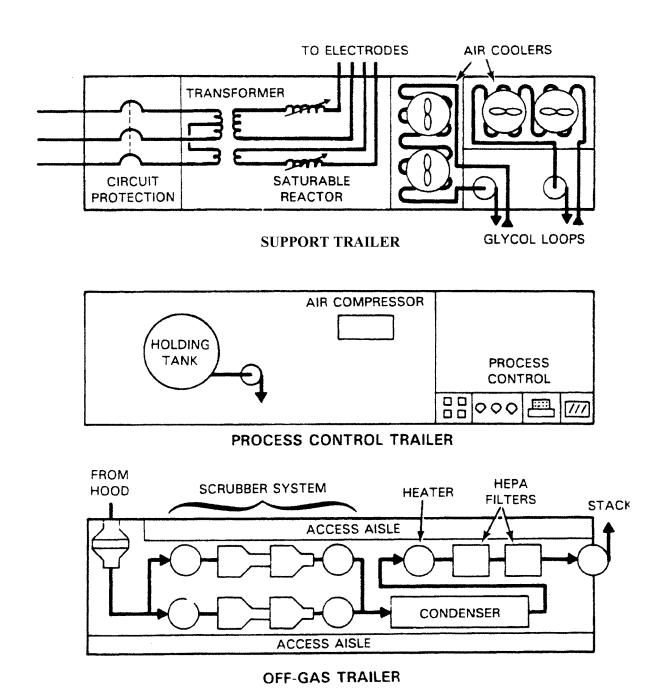


Figure 2-4. Layouts of the support, process control, off-gas treatment trailers.

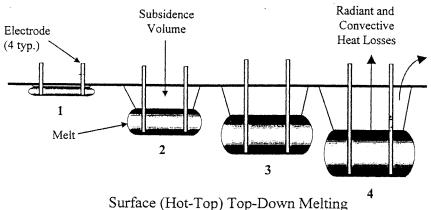
2.5.1 In Situ Vitrification Process

The ISV process works by melting soil and waste in place, using electricity applied between pairs of graphite electrodes that are consumed by oxidation as the molten zone grows. ISV melting typically involves molten soil temperatures in the range of 1,600 to 2,000°C. Site preparation includes the construction of a stable base near the melt location for placement of the ISV process equipment and installation of clean fill to level the site for the off-gas hood. A level laydown area for support equipment and process consumables is also provided. To initiate the ISV process, electrodes are inserted into clean overburden soil above the waste seam. Trenches are excavated in the clean overburden and a mixture of graphite and glass frit is placed between the electrodes to form a conductive starter path. Additional overburden may be placed to ensure that waste is not disturbed when placing the starter path and electrodes. An electrical current passed between the electrodes generates temperatures that melt the soil. The graphite is consumed by oxidation as the molten zone grows and incorporates the soil contaminants and produces a vitreous mass. Convection currents within the melt mix the refractory waste constituents (such as nonvolatile metals and radionuclides) to homogeneity while the remaining constituents are pyrolyzed in the subsurface or volatilized and processed by the off-gas treatment system.

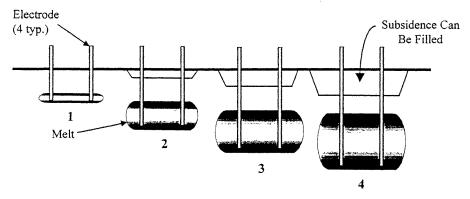
The starter path is created using a backhoe to excavate trenches that are filled with a layer of starter path material. Four steel tubes are inserted vertically and the trenches are backfilled with the excavated soil. The tubes provide holes for guiding the electrodes to the desired starting elevation. The electrode system consists of four graphite electrodes and the associated feeder assemblies. The electrode feeder assemblies, which are operated remotely, are located on the top of the off-gas hood. Each feeder maintains the vertical orientation of the electrode during processing and also provides the electrical connection between the electrical cables and the electrodes.

Each electrode feeder contains one set of pneumatically operated grippers. These grippers are used to control the electrode insertion depth. When the grippers are open, the electrodes feed by gravity into the developing melt. The electrode rides on the bottom of the melt, thus providing a depth gauge. By closing the gripper, the electrodes can be held above the melt bottom. A crane can also be used to raise, lower, or control movement of the electrode.

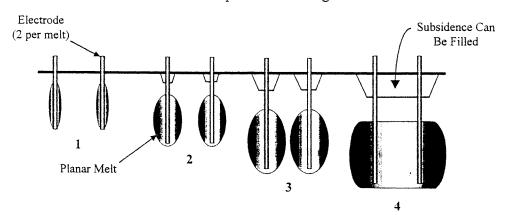
Each individual electrode is composed of several electrode segments. The segments have threaded couplings on each end. The couplings allow a number of electrode segments to be joined to form the desired electrode length. Electrode segments can be coupled prior to initiating the melt or during the melting process. The electrical connection is achieved by means of a set of copper contactor pads that are mounted to the electrode feeder frame. The pads have mounting plates and are spring loaded to ensure that contact between the contactor and electrode is maintained during operation. A highly conductive mixture of graphite and glass-forming compounds is placed in the soil between the electrode pairs and power is applied to the electrodes. The starter path heats and causes the surrounding soil to melt. The molten soil is electrically conductive. Continued application of electric current results in joule heating of the molten soil between the electrodes. Once the melt is fully established, the melt zone continues to grow into the waste seam. As the melt moves downward, the electrodes are gravity fed into the melt body to continue downward melt growth. Three techniques (melt growth patterns) for in situ vitrification have been employed in the past. These techniques are (1) surface (hot-top) top-down melting, (2) subsurface top-down melting, and (3) subsurface planar melting (see Figure 2-5).



Surface (Hot-Top) Top-Down Melting



Subsurface Top-Down Melting



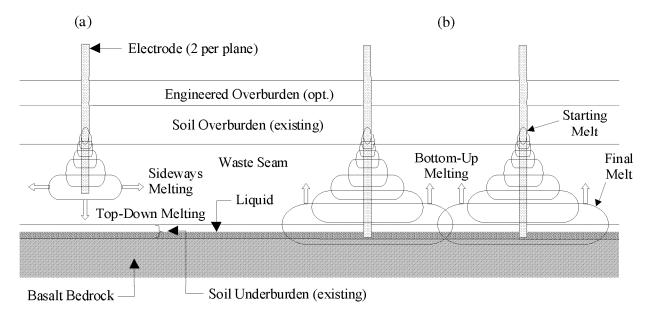
Subsurface Planar Melting

Figure 2-5. Illustration of melting configuration alternatives.

The surface (hot-top) top-down melting, as the name implies, originates at the surface and grows outward and downward. Subsurface top-down melting originates below grade.

The melt in the subsurface planar melting technique grows downward in a vertical planar fashion between an electrode pair. Subsurface planar melting involves forming one or more vertical planes of melt within the subsurface. Subsurface planar melting uses vertical planes of starter material to initiate ISV processing and applies current to pairs of electrodes. The melts grow downward and outward and eventually merge to form a single larger melt mass. After the subsurface planar melts merge into a contiguous mass, the bottom of the melt continues to move downward, and materials located above the melt are treated and incorporated into the melt, resulting in a rising of the top of the melt.

The typical subsurface planar melting progression is shown in Figure 2-6. This method results in narrower melts, and enables greater depth attainment than that possible by top-down melting. The SDA is believed to have water and perhaps other liquids present at the interface between the soil underburden and the basalt bedrock. Subsurface planar melting would approach such liquid accumulations from above with a comparatively smaller melt bottom area. Vapor is vented along the sides of the melts and thus reduces the potential for a melt expulsion. The subsurface planar melt starts with a small convex base, but over time, the melt becomes wider, and the shape of the bottom surface of the melt is more clearly described as concave-up. The fact that the melts are separated during much of the processing time promotes migration of gases up through the soil column between and around the outside of the melts during this stage of processing, which minimizes the potential for trapping pockets of gas under the growing melt. A cusp-shaped region is generated as the melts merge. By the time the melts merge, the wastes in this cusp region have had ample time to undergo thermal decomposition. The gases generated move upward through the soil column between the melt bodies and then to the off-gas treatment system.



(a) Sectional view of planar melt's progressive growth during downward melting, (b) Sectional view of two planar melts' progressive growth at point of reaching target depth in basalt and coalescing together into one large melt.

Figure 2-6. Subsurface planar melt progression.

2.5.2 Contaminant Fate

The fate of SDA contaminants during ISV processing was qualitatively evaluated in the ISV treatability study work plan⁹ and the results of the evaluation are shown in Table 2-1. During ISV processing, nonvolatile metals and radionuclides are chemically incorporated as oxides into the vitrified product. Volatile metals (such as mercury) are vaporized and processed by the off-gas treatment system. Organic contaminants are typically destroyed by pyrolysis in the subsurface, after which the pyrolysis products travel to the ground surface, where they are oxidized in the off-gas hood. Residual organic contaminants not destroyed in situ are passed through the ISV off-gas system and destroyed by the thermal oxidizer. Some residual volatile organic contaminants may migrate and deposit in the soils surrounding the ISV melt, while some semivolatile metals may partition and deposit below the melt. Additional studies may be required to determine if further treatment of these volatile organic contaminants is needed and to determine if partitioned metals are an acceptable waste form. Past vitrification work performed on high-level and TRU waste has demonstrated that oxides of uranium and plutonium are not reduced due to the high oxidation potentials and will therefore remain in the soil and be chemically incorporated into the vitrified product due to the high-solubility limits for radionuclides in glass, relative to the expected radionuclide contamination level in the pits. The ISV treatment produces a vitreous rock-like material that is free of organic material, has a compressive strength approximately ten times that of reinforced concrete, and is extremely leach resistant (similar to that of basalt or obsidian).

The high temperature of the ISV process vaporizes and/or pyrolyzes volatile and semivolatile contaminants as the ISV melt-front approaches the waste. Based on the boiling points compared to the boiling point of water and the melting point of soil, three classes of material are defined. Volatile materials have a boiling point less than 100°C. Semivolatile materials have a boiling point greater than 100°C and decompose or have significant partial pressures at temperatures less than the soil melting temperature, ~1000°C. Nonvolatile materials do not have significant partial pressures at ISV processing temperatures, that is, temperatures greater than approximately 1,100°C. In this context, significant partial pressure means that the partial pressure of the contaminant species is high enough to cause contaminant transport by gaseous diffusion. An additional mechanism affecting the fate of organic contaminants is the potential for in situ destruction (during or prior to volatilization) or ex situ destruction (following volatilization). The degree of in situ organic contaminant destruction (and contaminant migration potential) is also affected by the location of the particular contaminant, the size of the approaching melt, and the rate of melt progression (relative to that of the contaminant).

Table 2-1. Fate of SDA contaminants during ISV processing.

Contaminant	Contaminant Fate	Concern
Ac-227	Chemically incorporated in the melt.	None
Ag-108M	Reduces to metal, probably encapsulated in glass.	Minimal
Am-241	Chemically incorporated in glass.	None
C-14	Stays incorporated in metal slab that sinks to the bottom of the melt.	Minimal
C1-36	Dissociates and volatilizes during ISV processing. Pure beta emitter means very little dose concern. The closed nature of the ISV off-gas system eliminates inhalation concerns.	None
Co-60	Stays in irradiated metal, settles in metal slab at the bottom of the melt.	Minimal
Cr-51	Stays in metal slab that settles at bottom of melt. Low half-life makes this not a problem.	None

Table 2-1. (continued).

Contaminant	Contaminant Fate	Concern
Cs-137	Volatility and thermokinetic data suggest that Cs-137: (1) may volatilize and be collected on off-gas roughing filter (dose issue); (2) may be chemically incorporate in glass; or (3) may reduce to metal. This concern has since been resolved by recent tank vitrification tests (Geosafe 1998).	New test results confirm that this is not a problem
Eu-154	Chemically incorporated in glass.	None
Н-3	Volatilized and released during ISV processing and collected in off- gas scrubbers (as tritiated water). Pure beta emitter means that there is very little dose concern. The closed nature of the ISV off-gas system, coupled with its soluble nature, eliminates any inhalation concerns.	None
Hg-203	Volatilizes during ISV processing, collecting in scrub tanks. Low half-life makes this not a problem.	None
I-129	Dissociates and volatilizes during ISV processing. Small gamma release (38 keV), means that there is little dose concern. The closed, wet scrubbing nature of the ISV off-gas system eliminates any inhalation concerns.	None
Kr-85	Released as gas during ISV processing. Potential emission hazard.	Potential emission problem
Mn-53	Potential reduction to metal. Probably encapsulated in melt.	Minimal
Nb-94	Stays in irradiated metal. Settles in metal slab at the bottom of the melt.	Minimal
Ni-59 and Ni-63	Stays in irradiated metal. Settles in metal slab at the bottom of the melt.	Minimal
Np-237	Chemically incorporated in glass.	None
Pa-231	Chemically incorporated in glass.	None
Pb-210	Potential to reduce/stay in metal form and settle in metal slab at bottom of the melt. Potential to be chemically incorporated in glass. Slight potential for volatilization to off-gas if in metal, where it would deposit on roughing filter, where small gamma emission (46 keV) means there is little dose concern. An identified DATA GAP.	Possible product quality concern
Po-210	Only partially volatile contaminant. Most expected to stay in ISV melt. Residual collected in soil overburden or ISV off-gas system.	None
Pu-239 and Pu-240	Chemically incorporated in glass.	None
Ra-226	Chemically incorporated in glass.	None
Sb-124 and SB-125	Expected to reduce to metal form. Partial volatilization to off-gas, where it is collected on roughing filters (potential dose issue). Short half-life obviates this problem.	Minimal
Sr-90	Chemically incorporated in glass.	None
Tc-99	Stays in irradiated metal. Settles in metal slab at the bottom of the melt.	Slight product quality concern

Table 2-1. (continued).

Contaminant	Contaminant Fate	Concern
T1-204	Will readily reduce to metallic form. Slight potential for volatilization and collection in off-gas roughing filter. Pure beta emitter, so there is no dose concern.	Minimal
U-232, -233, -234, -235, -236, and -238	Chemically incorporated in glass.	None
Acetone	Volatilizes during ISV processing, concerns over contaminant migration to surrounding soil. Need to verify that volatilized volatile organic compounds (VOCs) are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Alcohols	Volatilizes during ISV processing. Concerns over contaminant migration to the surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Aluminum nitrate nonahydrate	Nitrates and nonahydrates dissociate and off-gas during ISV processing. Aluminum oxidizes and is chemically incorporated in the ISV glass.	None
Antimony	Expected to reduce to metal form, with a slight amount of volatilization to ISV off-gas system.	Minimal
Arsenic	Freely reduces to metal form, then volatilized and collected in ISV off-gas system.	Minimal
Benzene	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Beryllium	Oxidizes and is chemically incorporated in ISV glass.	None
Beryllium oxide	Chemically incorporated in glass.	None
1 ,4-bis (5-phenyloxazol-2- YL) benzene	Volatilizes during ISV processing. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
2-Butanone	Volatilizes during ISV processing. Concerns about contaminant migration to the surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Butyl alcohol	Volatilizes during ISV processing, concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Cadmium	Expected to freely reduce to metal during ISV processing, followed by volatilization and collection in the ISV off-gas system.	Minimal
Carbon tetrachloride	Volatilizes during ISV processing, concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Chloroform	Volatilizes during ISV processing, concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern

Table 2-1. (continued).

Contaminant	Contaminant Fate	Concern
Chromium	Stays in metal and sinks to the bottom of the ISV melt.	Minimal
Copper	Freely reduces to its metallic form during ISV processing, encapsulated in either glass or metal slab.	Minimal
Copper nitrate	Nitrates dissociate and are volatilized during ISV processing. Copper reduces to metal during ISV processing.	Minimal
Dibutylethylcarbutol	Volatilizes during ISV processing. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Diisopropylfluoro- phosphate	Volatilized during ISV processing. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Ether	Volatilizes during ISV processing, concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Ethyl alcohol	Volatilizes during ISV processing, concerns about contaminant migration to surrounding soil. Need to verify volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Hydrazine	Volatilizes during ISV processing, concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Lead	Identified data gap. May reduce to metal or be incorporated in glass. Slight potential for volatilization and collection on ISV off-gas roughing filter.	Possible produce quality concern
Mercury and mercury nitrate monohydrate	Dissociates, off-gasses, and volatilizes during ISV processing (as mercury, nitrogen gasses, and water). Whatever mercury does get into the ISV off-gas system must first pass through a HEPA prefilter before being cooled to 25°C in the Venturi scrubber and mist eliminator system. This results in the vapor pressure of mercury dropping to .00184 mm Hg, causing any mercury vapors above this level to condense and be scrubbed out by the Venturi scrubber and mist eliminator system. Any remaining vapor would then pass through the secondary HEPA filters at the end of the ISV off-gas system. This issue will be thoroughly evaluated in the air emissions evaluation.	None
Methyl alcohol	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
3-methylcholanthrene	Volatilizes during ISV processing. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Methyl isobutyl ketone	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern

Table 2-1. (continued).

Contaminant	Contaminant Fate	Concern
Methylene chloride	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Nickel	Stays in metal and sinks to metal slab at bottom of the melt.	Minimal
Nitric acid	Dissociated and off-gassed during ISV processing (as Nitrogen pentoxide and water).	None
Potassium nitrate	Nitrates dissociate and off-gas during ISV processing. Potassium goes to metallic form. Bulk quantities of potassium affect ISV electrical resistivity.	None
Silver	Reduces freely to metal, most likely encapsulated in the glass.	Minimal
Terphenyl	Volatilizes during ISV processing. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Tetrachloroethylene	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Toluene	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Tributyl phosphate	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
1,1,1-trichloroethane	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Trichloroethylene	Volatilizes during ISV processing. Concerns about contaminant migration to the surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
1,1,2-trichloro-1,2,2-trifluoroethane	Volatilizes during ISV processing. Concerns about contaminant migration to surrounding soil. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Possible contaminant migration concern
Trimethylolpropane- triester	Volatilizes during ISV processing. Need to verify that volatilized VOCs are destroyed by pyrolyzation and do not migrate away from the melt.	Unknown (possible contaminant migration concern)
Uranyl nitrate	Nitrates dissociate, off-gas, and collect in scrubber. Uranium is chemically incorporated in glass.	None
HEPA high-efficiency points in situ vitrification VOC volatile organic c	n	

A diagram of the anticipated environment at the edge of the ISV melt, during ISV processing, is shown in Figure 2-7. With a hood diameter of 60 ft and a final melt diameter expected to be on the order of 12 m (40 ft), ¹⁰ the hood encompasses the entire melt area. The environment at the edge of the ISV melt consists of a series of thermal zones surrounding the periphery of the melt. These include the fusion zone (where soil and waste is melted and incorporated into the melt), the dry zone (between the edge of the fusion zone and the 100°C isotherm), the condensation barrier (or 100°C isothermal zone, where moisture in the soil is evaporated), and the ambient zone (between the cold side of the 100°C isotherm and ambient soil temperature).

During ISV processing, nonvolatile, and semivolatile materials are incorporated into the melt or captured by the off-gas system. Semivolatile materials migrate to the ISV off-gas system through the dry zone between the ISV melt-front and the 100°C isotherm. Volatile components are expected to be pyrolyzed in the dry zone or transported to the off-gas treatment system by vaporized water leaving the dry zone. A small amount of water soluble organic constituents may diffuse into the surrounding soil and bedrock through the wet zone.

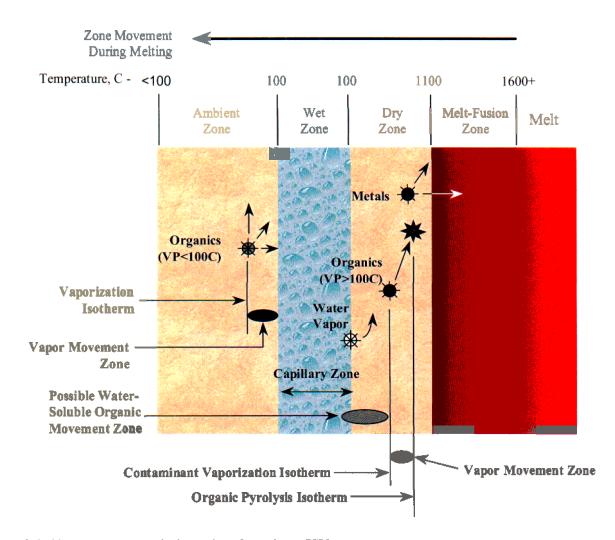


Figure 2-7. Vapor movement during subsurface planar ISV.

The primary mechanisms affecting contaminant movement relate to the enhanced permeability of the dry zone (due to an absence of soil moisture and the destruction of carbonate and hydrated minerals during ISV processing). The enhanced permeability allows water and organic contaminant vapors to be transported through the dry zone with much less resistance than other thermal zones. Furthermore, the dry zone is located between the edge of the fusion zone, which behaves as a dense barrier with significant static-head pressure, and the moisture-saturated 100°C isotherm, which serves as a barrier to vapor transport away from the melt. Therefore, the primary pathway for vapor transport during ISV processing is through the dry zone around the ISV melt, toward the ISV hood plenum. During ISV processing, the thermal gradient through the dry zone is estimated to be 125°C to 380°C per inch of soil, and the thickness of the dry zone during ISV processing is typically between 9 and 12 in. Further evaluations will be required to understand the performance and safety implications of ISV processing in heterogeneous debris and sludge waste such as found buried in the SDA. The evaluation should also consider ISV processing in waste regions with voids.

Semivolatile materials become mobile in the dry zone, either volatilizing or decomposing, because the boiling points are greater than water. At their boiling temperature, semivolatile materials are confined on the low-temperature side by the low permeability (relative to the dry zone) transition zone material, the liquid-water barrier, and the boiling-water region of the 100°C isotherm. On the high-temperature side, the semivolatile materials are confined by the advancing melt-front. The avenue of least resistance is movement through the dry zone to the overburden and eventually to the ground surface, which is the same path followed by water vapor. If the temperature of the path exceeds approximately 400°C, semivolatile materials are often partially or completely decomposed, that is, pyrolyzed. If the temperature of the path is less than 400°C, the semivolatile materials move to and through the overburden ground surface, where they are retained and processed by the off-gas system. If the semivolatile materials are liquid, they are wicked by capillary forces from low- to high-temperature regions where they may be volatized or decomposed. In general, the semivolatile materials and the associated pyrolyzation products are swept through the dry zone as a component of the dominant steam flux into the off-gas system. When the volatile and semivolatile materials reach the relatively cool overburden, they may recondense. Eventually, as the overburden is consumed in the ISV melt, these materials revolatilize and make their way into the off-gas system or are destroyed by the melt.

2.5.3 Postoperation Activity

After ISV processing, samples of the off-gas system scrubber solution, off-gas system filters, and system internal smear samples are taken to determine appropriate methods for waste disposal, and to confirm that the equipment can be safely moved to the next treatment site within the SDA.

SDA operations management, with industrial hygienist and radiological control support, determines when the off-gas system operations can be terminated in accordance with the radiological protection and industrial hygiene programs. Once the sampling of the ISV systems is completed, all secondary wastes are disposed of, and operations management has determined that the ISV systems can be moved safely, all system components and process-related items are moved to the next treatment location. The amount of subsidence not filled during melting is measured and recorded. The subsidence area is then filled with clean dirt and graded to match the SDA surface.

After ISV has been completed and the equipment has been removed, a low-permeability, multilayered cap is constructed over the SDA to protect any remaining waste and residual soil contamination by deterring biotic intrusion, facilitating run-off of precipitation, and further reducing the infiltration of moisture into the waste zone.

2.6 Confinement Systems

The confinement systems are the existing and engineered overburden, the off-gas hood, and the off-gas processing system. Each of these is discussed in more detail in the following subsections.

2.6.1 Overburden

The overburden or fill material used to cover the disposed waste acts as a confinement system for subsurface explosions and prevents melt expulsions. The overburden also serves as a filtering medium for off-gases produced during the melt. The existing overburden depth at the SDA is as little as 3 ft and as much as 8 ft thick.

2.6.2 Off-Gas Treatment Hood

The off-gas treatment hood contains the gaseous effluents from ISV processing, provides a confined area for oxidation of the effluents, and directs the effluents to the off-gas system. A simplified drawing of the off-gas treatment system including the hood, and inlet and exhaust lines is shown in Figure 2-8. The hood measures 60 ft in diameter and is octagonal in shape. The final melt diameter is expected to be on the order of 12 m (40 ft)¹⁰ and the 60-ft-diameter hood encompasses the entire melt area. Lifting attachment points are located on the hood so that the assembled hood can be repositioned using a crane. The hood is constructed of stainless-steel panels and is bolted and gasketed together in a manner that relieves stresses caused by nonuniform thermal expansion. The hood is connected to the off-gas trailer by sections of off-gas line. Because the hood supports the graphite electrodes via insulators, the hood is grounded.

A 6-in. air inlet and valve controls air flow into the hood and correspondingly controls the hood vacuum. A back-up blower rated at one quarter the capacity of the primary blower is provided in case of failure of the primary blower. The secondary or back-up blower is not designed to pull excess inlet air into the hood, but rather to maintain a negative pressure on the off-gas hood to prevent direct release of effluent until the process can be safely shut down. The backup blower is automatically activated by the process control system when the hood vacuum falls below a preset limit.

2.6.3 Off-Gas Treatment System

An off-gas HEPA prefilter system (see Figure 2-8) is employed between the off-gas hood and the off-gas treatment trailer. This system consists of propane-fueled gas flame preheater units, high-temperature HEPA filter units, and a by-pass line. The housings for the preheater units and the HEPA filter units are bolted into the off-gas line using standard flanges. The system contains manual control valves that allow the off-gas to be routed through either or both housings or to bypass both housings. The HEPA filter units are supported on a structure, which allows for changing of the filters. Differential pressure drop is measured across the HEPA filter housing to monitor solids loading on the filter units. The off-gas HEPA prefilter design was initially tested in the 1991 radioactive pilot-scale test at Oak Ridge National Laboratory (ORNL)¹² and was found to be extremely effective in removing Cs¹³⁷ activity from ISV off-gas. System effectiveness was further demonstrated during large-scale radioactive operations at ORNL¹³ and at LANL.¹⁴

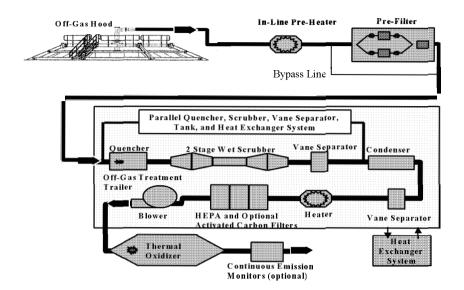


Figure 2-8. Simplified flow diagram of the ISV off-gas treatment system.

The off-gas treatment system, which cools, scrubs, and filters the gaseous effluent exhausted from the hood, is contained in the off-gas trailer (see Figure 2-4). The off-gas trailer is enclosed and contains an internal containment module. The containment module houses and isolates the off-gas treatment equipment. The containment module, which is a large glovebox constructed primarily of stainless steel, isolates operators from processing equipment and protects them from being contaminated during an abnormal condition.

2.7 Safety Support Systems

Safety support systems include the process control, glycol cooling, fire protection, hazardous material monitoring, and heating, ventilating, and air conditioning (HVAC) systems. Each of these is discussed in the following subsections.

2.7.1 Process Control

The process control station located in the process control trailer consists of a process monitoring and control system and a control system console for the power supply. The process control system monitors and controls important process parameters and automatically activates backup equipment or reroutes off-gas flow in the event that certain equipment fails.

The process control system consists of a central process control unit (PCU) and two operator interface units. The PCU is connected to sensors located throughout the process equipment. These sensors include readings from pressure sensors, thermocouples, gas monitors, and flowmeters. In addition to monitoring important parameters, the PCU regulates the pressure drop across the scrubber system by opening and closing a pneumatic valve that governs the magnitude of recycle through the main blower. The control system automatically activates the standby scrubber system if hood vacuum falls below setpoint levels. Activation of the standby scrubber system subsequently increases the flow capacity of the process. The control system also provides automatic batch logic sequencing of specific operations in case of equipment failure. For example, the control system can automatically restart the off-gas system in a preprogrammed sequence in case of power failure, and can automatically activate the parallel HEPA filter

assembly if pressure drop across one housing exceeds predetermined levels. Also, the system automatically shuts down power to the melt and starts the backup or secondary blower upon primary blower failure.

Although the control system is connected to sensors and to an automatic shutdown circuit on the 3,750-kVA power supply system, the control system does not directly control the power supply. A separate power supply controller regulates the saturation current to the saturable reactors that govern the power to the electrodes. This control module maximizes the efficiency of the electrode power system and provides a quick reduction in power in case of off-standard conditions.

2.7.2 Glycol Cooling System

The primary function of the cooling system is to cool the condensate from the quencher, scrubbers, and vane separators (mist eliminators). Glycol cooling solution is passed through the glycol cooling assembly on the support trailer to remove the heat from scrub solution that has quenched the gaseous effluents. The assembly consists of two fan-cooled radiation systems, each dedicated to and separate from its respective glycol loop. The entire assembly, which fits on the front of the support trailer, removes 1,600 kW (91,000 Btu/min) at an ambient temperature of 38°C (100°F). The glycol is recirculated by two pumps in two independent loops between the support trailer and the off-gas treatment trailer through flexible jumpers. The glycol loop for the heat exchangers and condensers is kept separate from the glycol loop for the gas cooler.

2.7.3 Fire Protection Systems

There are no automatic fire suppression systems in the process trailers or off-gas hood. Fire suppression is performed by using handheld fire extinguishers located in the three process trailers. The handheld fire extinguishers meet the requirements of the National Fire Protection Association (NFPA) standard 10.15 Additional fire protection support is available through the INEEL Fire Department. However, this support is limited, because there is no permanent water supply in the SDA to support manual fire suppression activities. The INEEL Fire Department maintains three stations on the INEEL. The main station is located in the CFA. Substations are located at Test Area North (TAN) and Argonne National Laboratory-West (ANL-W). All three fire stations are staffed 24 hr/day by career firefighters. Each of the three stations has the equipment and expertise to respond to explosions, fires, spills, and medical emergencies. Because there is no permanent fire water supply for fire department operations in the SDA, water supply for fire fighting operations is inadequate. This limitation requires further analysis in the fire hazard analysis that will be prepared to support a final DSA for ISV.

2.7.4 Hazardous Material Monitoring Systems

Hazardous material monitoring directed by the RWMC radiological engineers and industrial hygienists is performed using portable monitors. In addition to the portable monitors, permanent toxic gas (such as carbon monoxide) monitors are installed around the periphery of the off-gas hood and in all occupied areas. Emissions from the off-gas-treatment system are monitored in accordance with associated air permits.

2.7.5 HVAC

Ventilation in the areas occupied by operating personnel in the off-gas and control trailers is provided to maintain comfortable working conditions. The control station and ancillary equipment area are serviced by one HVAC system in the control trailer. In addition to a comfortable working environment, the control trailer HVAC system must provide clean, controlled conditions for the process

control equipment. The ventilation in the aisle of the off-gas trailer is separate from the ventilation in the containment module of the off-gas trailer. The open flatbed support trailer is not equipped with an HVAC system. However, the dry-type transformer on the support trailer is cooled with forced air when operating and includes electrical heaters to minimize condensation.

2.8 Utility Distribution Systems

The utility distribution systems are external (outside the ISV operation) and internal (at the ISV operation) electrical power, water, and propane. Each of these is discussed in the following subsections.

2.8.1 External Electrical Power

Power is supplied to the RWMC by a 12.5-kV line from the Scoville substation at CFA via Experimental Breeder Reactor-I (EBR-I) to Pole E-133. Pole E-133, located north of WMF-655, supplies power to a 600-A vacuum fault interrupter (N-SCSW-MC01). Power is routed underground in an existing loop configuration to various 15-kV fused load break sectionalizing terminal posts throughout the RWMC area. This power loop arrangement allows some flexibility in routing power throughout the facility. The sectionalizing terminal posts are dedicated to specific stepdown transformers to meet voltage requirements. Also, an existing 12-kV line is routed underground near the Pit 9 area, then overhead to supply power around the perimeter of the SDA. Temporary aboveground power lines will be run to the ISV electrical trailer. The high-voltage electrical distribution system is maintained and operated by the INEEL Power Management organization.

2.8.2 Internal Electrical Power

The onsite electrical power supply, housed on the support trailer, provides and regulates power for soil melting. The system is composed of a 15-kV power supply disconnect and 3,750-kVA Scott-Tee transformer, which has 16 different voltage taps. A Scott-Tee transformer converts three-phase (3-wire) power to a balanced two-phase (4-wire) system. Voltages on the load side are provided from 4,160 V to 440 V at an amperage from 450 A to 4,000 A per phase. Saturable reactors, on each phase in series, load control power to the melt between voltage taps for maximum efficiency, safety, and control.

Power to the 3,750-kVA power supply is typically provided at 13.8 kV (or 12.47 kV) and can be interrupted by the 15-kV circuit protection switchgear located adjacent to the power supply. Power can be shut down at the switchgear or remotely from the control panel. The switchgear can be serviced through removable side panels. Power interruption to the 3,750-kVA power supply will not interfere with the power to the off-gas equipment.

The ISV system includes a backup power supply that provides power to the off-gas treatment system in the event of a loss of commercial power. This system provides emergency power to all off-gas system and ancillary components to maintain off-gas collection, treatment, and process control. The backup generator does not supply power for melting soil.

2.8.3 Water System

Water is supplied to the RWMC by a 240-gpm deep-well pump (production pump) located in WMF-603. The water is pumped into the 250,000-gal water storage tank (WMF-709). Potable water is supplied to buildings by two 250-gpm domestic supply pumps. There is no potable water or water for fire suppression supplied to any area of the SDA. Makeup water for the scrubbers will be required.

2.8.4 Propane Supply

Propane for heaters in the off-gas treatment system, the HVAC systems, and the thermal oxidizer is supplied from an as yet unsized propane tank adjacent to the three process trailers. The system design includes leak protection, overpressure protection, natural phenomena protection, and barriers to protect the tank from vehicle impacts. A defoliated buffer area is provided around the propane tank. Propane storage is managed in accordance with the requirements of the NFPA 58, "Standard for the Storage and Handling of Liquefied Petroleum Gas." Prior to completing the final documented safety analysis (DSA) for ISV at the SDA, analyses must be completed to define the size of the propane tank and to estimate the refueling frequency.

2.9 Auxiliary Systems and Support Functions

The auxiliary and support systems are the communications, auxiliary lighting and power, and off-gas support systems. Each of these is discussed in the following subsections.

2.9.1 Communications

Wireless communications are provided to the system operators for operational control and safety. For example, an operator adjusting a valve in the off-gas trailer can be in constant contact with the operator monitoring the process from the process control trailer.

2.9.2 Lighting and Power

Indoor and/or exterior lighting is provided on all three process trailers. Outdoor electrical services are provided for air sampling and other support equipment. Low-voltage power for all lighting and communication services is provided by a circuit that is independent from the high-voltage soil-melting power supply.

2.9.3 Off-Gas Support Systems

Various support and backup equipment are necessary to ensure the safe operation of the off-gas system. These systems provide electrical, water, and air services to the off-gas equipment.

The process control trailer houses the scrub solution supply tank and the air compressor. The scrub-solution supply tank provides makeup water storage for additional scrub solution as required by the process. The scrub-solution supply tank is equipped with an agitator for mixing chemicals such as NaOH, and a pump for transferring solution to the off-gas treatment trailer process tanks. At the direction of the operator, fresh scrub solution can be pumped from the supply tank to the scrub tank through flexible jumpers located between trailers. However, the system is designed with a check valve so that contaminated scrub solution cannot be pumped back to the process control trailer. The air compressor provides instrument air at 520 to 690 kPa gauge (75 to 100 psig) for the pneumatic actuators on the butterfly valves. Air is supplied to the butterfly valves through flexible jumpers between the process control trailer and the off-gas treatment trailer (or hood).

2.10 References

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